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The Effect of Water on the Durability of Granitic Materials Consolidated With Ethyl Silicates

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(biographies and contact information for authors can be found at the end of this paper)

Abstract

This paper presents the results of an investigation of the action of water on granitic materials consolidated with commercial formulations of ethyl silicates.

Three types of actions were tested in the laboratory:

- cycles of temperature and humidity
- long-term water immersion
- cycles of absorption followed by drying of liquid water

Ultrasound measurements were used to monitor changes during the “aging” processes. [Existing knowledge in this field allows us to consider this method one of the best choices for characterization of fissured rocks such as granites, in particular when used in a comparative manner.]

The results of these tests indicate that these ethyl silicates currently used in conservation are sensitive to the action of water. Although this sensitivity is not limited to these products, they are particularly vulnerable — even if the consolidant has a composition that makes it water-repellent.

Titre et Résumé

L'effet de l'eau sur la durabilité des matériaux granitiques consolidés avec des silicates d'éthyle

Dans le présent travail nous avons étudié l'action de l'eau sur les matériaux granitiques consolidés avec différentes formulations commerciales de silicates d'éthyle fréquemment utilisés en restauration et conservation de la pierre.

Les essais de laboratoire comprenaient trois types d'actions :

- les cycles de température et d'humidité;
- l'immersion prolongée dans l'eau;
- des cycles d'absorption de l'eau suivie de séchage.

Pour évaluer les changements qu'entraînent les processus de « vieillissement », on a utilisé la vitesse de propagation des ondes élastiques. La vaste expérience acquise avec cette méthode indique qu'elle est l'une des meilleures solutions pour la caractérisation de roches fissurées comme les granites, en particulier lorsque le procédé est utilisé dans une perspective comparative.

Tous les essais indiquent que les silicates d'éthyle sont sensibles à l'action de l'eau. Bien que cette sensibilité n'est pas exclusive à ces produits, ils sont particulièrement vulnérables, et ce,

même si un effet hydrofugeant complémentaire, associé à la composition de l'agent de consolidation, est présent.

Introduction

Ethyl silicates, as they are known by practitioners or referred in conservation literature, are a large family of products used for a long time as consolidants on several types of materials, namely on stone. Since the very beginning they were extensively used to consolidate limestones, sandstones or marbles and an important number of publications after Laurie and Schaffer (1932) and then Bosch (1972) present results on their behaviour on these types of substrates were published. Their use to consolidate granitic materials is more recent and in some way conditioned by a prejudice involving the inability to consolidate granitic materials, still very current in the 1990s.

Past builders of our monuments often sculpted and shaped already decayed materials extracted from local outcrops used as quarries. The pollution and the systematic use of incompatible materials in modern times introduced other relevant decay agents. The use of incompatible mortars (with some Portland cement incorporated, for instance) is recognized harmful factor for stone. Flaking, contour scaling and granular disintegration are very common in granitic decayed surfaces and responsible for the fast erosion rates observed in practice.

Granitic materials present in monuments are characterized by the existence of fissure-like voids and low porosity, but also by a high variability of mineral composition and textures, where quartz and feldspars are the major components. All these distinctive aspects control the physical and mineralogical characteristics of those materials and are key-parameters in consolidation, namely when alkoxy silanes are involved to achieve a mass consolidation effect.

Generally speaking and despite the great variability of compositions available on the market, ethyl silicate-based products are recognized for their good capability to penetrate deeply into the materials and therefore a bulk consolidation of decayed material can be reached. In fact, the low viscosity and the ability to form Si-O-Si bonds, considered relatively strong and stable, are two properties often cited to justify the use of alkoxy silanes for the consolidation of stone, even when exposed to outdoor conditions. The chemical similarity of these gels with silicate minerals was used to support the idea of great resistance when submitted to weathering; actually, silicate minerals are not always stable phases and these gels are not comparable to them. Nevertheless, the gels formed after hydrolysis and condensation of ethyl silicate-based consolidants are chemically compatible with silicate substrates, fulfilling one important selection criterion for the choice of the product to be used. The information available (Elfving and Jäglid cited in Wheeler 2005, p. 39, 40) indicates the possibility of chemical bonding between the major granite components (quartz and feldspars) and the gels formed.

Some words must be added about the context of this work. In the frame of the “Granitix Project”, an European Commission research project (1991-1994) on degradation and conservation of granitic rocks used in megalithic monuments, several types of consolidants were tested in laboratory conditions, including Wacker OH. Later, this subject was pursued using different products and tests involving Rhodia ethyl silicates. More recently, the works of

Wheeler (2005) and (2008) on alkoxy silanes used in stone conservation added practical and relevant information about the characteristics, behaviours and diversity of the gels allowing us to better understand our own results, some still unpublished.

For all these reasons, in this paper some information obtained on different “ageing” tests performed in the laboratory is compiled. Different varieties of granites were treated with some of the most currently used commercial ethyl silicate-based products. The results are presented and discussed, taking into consideration the consequences of their behaviour for the in-practice consolidation of granitic materials.

Some Relevant Questions Concerning the Consolidation of Granites with Alkoxy silanes

As it is well recognized, the efficiency of a consolidant is determined by the capability of the liquid to migrate inside the system of voids. For alkoxy silanes, the product’s viscosity and the composition of the solvent, among others, determine the properties of the formed gel; the formation of this gel starts with hydrolysis followed by condensation reaction, making the presence of water molecules crucial for the polymerization to progress.

Even when decayed, granites are low porosity rocks and absorb small amounts of product. Consequently, very low quantities of product remain inside the porous network after polymerization. In these circumstances, it may be questioned whether the desired consolidation can be guaranteed when only a small amount of consolidant is present inside the material.

Some laboratory results can clarify the doubts and ultrasonic methods are considered very useful to evaluate stone consolidation in this context.

For those who are not familiar with this technique some notes can be helpful. Natural hazards like earthquakes generate elastic waves that can travel and reach distant points. As it is well known, the reception of P-waves in a network of geographic points allows the fast identification of the epicentre, just after the earthquake. Less known is the application of the same principle in other fields of science. UPV method (“ultrasonic pulse velocity”) is one of these methods well established in civil engineering not only to control the quality of concrete and to detect the presence of cracks but also for the testing of stone. Later on, the technique was introduced in stone conservation by Mamillan (1972) to evaluate stone decay in monuments and to control the efficacy of consolidants.

In laboratory or in the field several set-ups can be used but one of the most relevant parameters to be computed is the velocity of P-waves propagation. The values depend on the properties and the structure of the material but also on several parameters like the presence of fissures and cracks or moisture content. In general, the sound travels faster in denser materials and slower in water or air. For all these reasons, it allows to assess the degree of deterioration of the stone and the modifications promoted by the products after consolidation.

Coming back to the laboratory tests, when in direct contact with decayed granites, the product is absorbed at a quite fast rate that can be compared to the rates found in stones with much higher porosity. As an example, Wacker OH applied to a very porous limestone (open porosity of about 28%) and to a moderately weathered granite (2.3%) was absorbed in very different amounts (respectively 11.7 and 1.1 kg/m² in Figure 1A), but the filling rates (percentage of filled pores over time) are very similar (Figure 1B). After the application and in spite of the apparently low amount of product absorbed, the consolidation effect was very relevant, as can be seen in Figure 1C by the increase of the ultrasonic velocity in the treated zone of the prism. The original velocity obtained in the prisms before treatment (1500-2000 m/s, identified as “non treated granite” in the figure) was increased to around 2700 m/s after consolidation. Moreover, the increase of ultrasound velocity from 2700 to 3500m/s on the base of the prism (the firsts 1.5cm) allows detection a concentration of the consolidant. It is also noticeable the interface of the treatment on the top of the sample marked by the slowly decrease of the velocity.

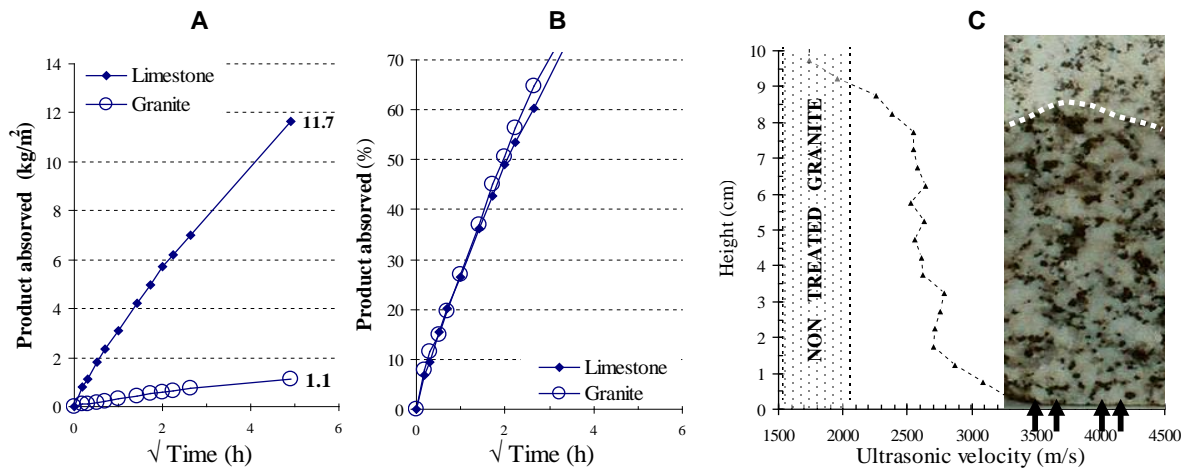


Figure 1 – Absorption curves of Wacker OH in granite and limestone (A and B) and the consolidation action evaluated by ultrasound velocity in a granite specimen (C). Note: In C, the liquid fringe reached the top of the prism (about 9cm height) and after polymerization, in the treated zone, the propagation of P waves is faster due to the better connection between the mineral components of the rock.

The general conclusion is that, even in small amounts, this consolidant has a bonding effect quantifiable by non-destructive methods like ultrasonic velocity measurements, particularly useful on the characterization of fissured rocks. The mechanical strength results obtained in these samples also allow the same conclusion published by Vicente et al. (1996a) or Delgado Rodrigues et al. (1996a).

The efficiency of consolidation depends on the characteristics of the gels formed. We believe that the durability of treatment is also dependent on them. As it is known, the “curing” or “polymerization” involves hydrolysis and condensation reactions that produce the gel. However, gels can have different characteristics depending on several factors such as; the original composition of the product, the prevailing environmental conditions and the chemical composition of the substrate, which seems to control the chemical bonds of newly formed gel.

The characteristics of gels formed are actually recognized as a key-aspect of the global performance of consolidation, yet the control of their properties inside the consolidated materials is not a simple task. Evaporation curves, similar to those presented in Figure 2, indicate different steps, namely the gelation process, here identified with arrows on B; the evaporation almost ceases, which means that the gel was formed (Wheeler 2005). In open-air conditions, after about 48 hours, the gel cracks. In this example the two gels are morphologically very similar in the end (Figure 2A), but it is worth noting that, under informal observation, the gels formed during laboratory consolidation applications usually present a higher index of cracks.

Inside the stone, the process seems to be slower and it is probably different when compared with open-air conditions, but it is very similar when we consider very different stone substrates and consolidants (Figure 2C in comparison with 2B). Although informative, mass assessment over time is not able to give information about the characteristics of the formed gels, namely their crack indexes.

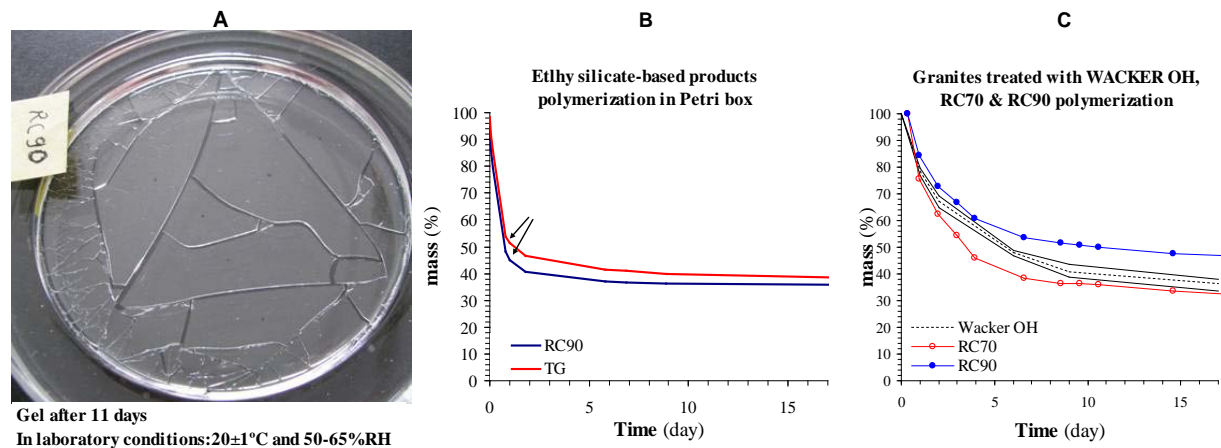


Figure 2 – Aspect of an alkoxy silane in a Petri dish (A), and mass loss during polymerization in open-air conditions (B) and inside the granite specimens (C). Note: In 2C, open porosity of granites: 2.6% (curves in black), and 5.5% (curves in blue and red); Consolidants: Wacker OH - TEOS in acetone; RC70 - TEOS in white spirit; RC90 - TEOS with methylphenylsilicone resin in white spirit and toluene.

The cracking of the gel is a characteristic phenomenon during alkoxy silanes polymerization. The integration of flexible segments into the network of gels (Wendler 1996) or the inclusion of small particles (Yang 1998) have been proposed to decrease this effect that is considered undesirable in consolidation actions. Commercial products with components to reduce cracking are already available in the market. Research on the efficacy of the products when applied to granites is in progress.

Besides original composition of the product, the influence of the environmental conditions on polymerization is also recognized, namely the relative humidity (RH) conditions prevailing during polymerization of gels (Charola et al. 1984 cited in Wheeler 2005, p. 63). The influence of temperature or the possible contact with liquid water on the properties of formed gels are not so evident.

Besides the observation of open-air polymerization of gels and the study of treated samples under scanning electron microscopy (SEM), to our best knowledge there are no systematic studies that correlate cracking degree, efficiency and durability of consolidation treatments for this family of products.

Inside the porous system of the rock, we tried to follow the process using the changes on the water vapour transfer due to the opening of cracks. For this, we used the set-up of the water vapour permeability test based on RILEM (1980). It consists of a box where the environment was maintained constant (at 75% RH in the case). Small cells with slices of treated stones were mounted and sealed. The transfer of water vapour is made exclusively through the stone, from the outside to the interior of the cells. Regular weighing of cells (Figure 3C) allowed computation of the rate of vapour water transfer. As it is clear from the results in Figure 3A, the opening of cracks is responsible for the atypical shape of lines due to the changes in water vapour transfer in time, namely in the first part of the test (just few days after the application of the product). Initially the water vapour transfer is very low (step “a”), and it increase in “b” and after in the “c” step of the process. These results also support the consideration that the gel is gradually changing, at least during the 15-20 days of polymerization (transition from regime “b” to “c”). This interpretation of the results is based on typical results of the test, namely on “non-treated granite” and granites consolidated with Wacker OH, plotted also here for comparison (Figure 3 B).

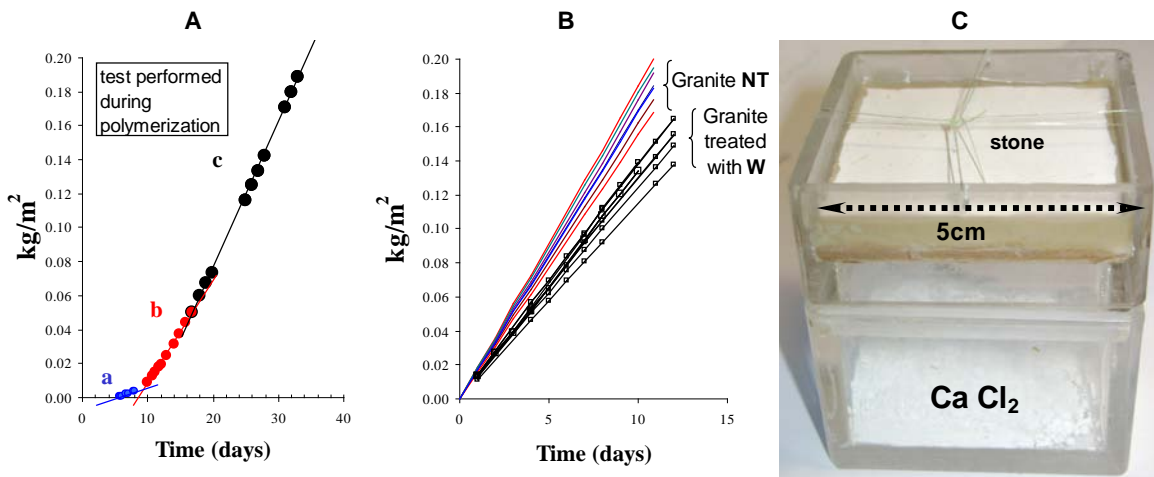


Figure 3 – Water vapour permeability of samples treated with Wacker OH during (A) and after (B) polymerization. The picture in C represents a cell used to test a limestone sample. Note: Values measured with the “dry cup” method, at 75%RH gradient, in laboratory conditions (20 ± 1 °C). Additional information: “NT”- non-treated; “W”- Wacker OH.

The use of this method to evaluate the cracking of the gel must consider some additional effects: water is needed for hydrolysis and the evaporation of the solvent promotes a mass loss, the interpretation of the results is more complex than it seems at first glance.

In summary, from the results it can be considered that this test is potentially useful to evaluate the crack index of the gel inside the material, in particular if used in a comparative basis to

evaluate stone consolidation involving alkoxy silanes. Additional research is needed to evaluate the possibility of using it to follow physical changes of gels inside the materials or alternative methods for this purpose.

Methods Used to Evaluate the Influence of Moisture on Durability

Water is one of the most powerful agents of promoting chemical, physical or mineralogical changes in materials, as well as the transport and deposition of components that can take a decisive role on decay. Due to the brittleness and fragility of the gel, ethyl silicate-based consolidants can be particularly sensitive to the action of water, although the field evaluation in some places indicates that the consolidation action can last for one or two decades (Martin et al 2002 cited in Wheeler 2005, p. 89,94).

The action of salts and salty solutions on consolidated materials is usually a concern that justifies the vast number of studies published in the literature. The effect of water (in liquid or vapour phase) is less studied and the research involving granites is even scarcer still.

To evaluate the behaviour of different ethyl silicate-based consolidants applied to granitic materials when exposed to moisture conditions three types of tests were performed:

- Test A - cyclic changes of temperature and relative humidity,
- Test B - long-term immersion,
- Test C - wetting and drying cycles.

For these tests, two types of specimens were prepared (prism-shaped “P”, and cubic-shaped “C” specimens) and treated with three ethyl silicate- based consolidants: Wacker OH, Rhodorsil RC70 and Rhodorsil RC90 from Rhodia (identified as RC70 and RC90 in the text). They are commercial products very well known and studied in stone conservation. All of them are ready to use formulations and for this reason they were used as supplied.

The “P” specimens (with open porosity of 2.6%) were consolidated with Wacker OH by partial immersion to guarantee a full impregnation. Samples of 1.5 x 3.5 x 12cm and 2.5 x 2.5 x 12cm were immersed up to 2/3 in height for 14 h and subsequently turned upside down for the next 10 hours.

Table 1 presents the quantities of product applied and retained after polymerization.

Table 1 – Wacker OH applied and retained in the consolidated granite (“P” specimens)

Product applied by immersion /full impregnation	Product retained after polymerization (dry mass)	
	(kg/m ³)	(%)
Wacker OH	9.5	0.37

The specimens “C” were consolidated with RC70 and RC90 by capillarity, from the bottom to the top of the cube (Costa 2007). In this case, a different granite was used (open porosity: 2.0%).

Table 2 presents the quantities of the products applied and retained after polymerization.

Table 2 – Rhodia ethyl silicates applied and retained in the consolidated granite (“C”specimens)

Product applied by capillary absorption	Product retained after polymerization (dry mass)	
	(kg/m ²)	(%)
RC70	0.5	0.04
RC90	0.7	0.08

Test A - Temperature and humidity cycles

Specimens were tested in an automatic chamber from HERAEUS, programmed to reach events of water condensation on the surfaces of the specimens during each cycle of heating and cooling. Each cycle lasted for 8 hours (Figure 4). The test was conducted for 380 cycles; periodical non-destructive characterization was done after 120, 150, 280 and 380cy. “P” type specimens were used for this test.

Some samples were characterized with destructive methods to evaluate the mechanical resistance after 150 and 380cy to complement the characterization done with ultrasonic methods present in this paper. The results were published by Vicente (1996b) and Delgado Rodrigues (1996b).

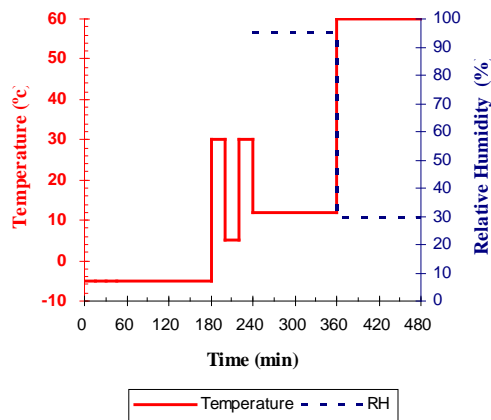


Figure.4 – Cycle of temperature –humidity

Test B – Long-term immersion

In this case, specimens were simply immersed in demineralised water for about 160 days. After 40 days the test was momentarily interrupted, specimens were dried and characterized. Periodically the water was changed and specimens removed to be characterised with non-

destructive methods in wet condition. “P” type specimens were also used in this case (Vicente 1996b; Delgado Rodrigues 1996b).

Test C - Water absorption/drying cycles

This test was performed in two steps; a short wet phase followed by a long dry period. Water was applied by capillarity until it reached the specimen top and the water content was stabilized. Lateral faces of specimens were then covered to allow a unidirectional flux and let to dry in laboratory conditions until a constant mass was reached (usually not less than one month). Each cycle lasted for about 2 months and four “cycles” were done (identified as “W.1” to “W.4”). For this test “C” type specimens were used.

In the case of tests A and B, changes were evaluated with ultrasound velocity (compression P-waves), mechanical resistance (bending strength), porosity and mass variation. Other properties relevant for the use of consolidants in conservation practice, such as colour changes, were also monitored. In the case of test C ultrasound velocity was measured along profiles (as in Figure 1C). The results here presented were determined in dry conditions; in this case, specimens were dried in a ventilated oven at 60°C (for about 72 hours or until the “constant mass” criteria was reached).

Results and Discussion

Test A

The effect of temperature/relative humidity cycles on the consolidation action of Wacker OH was monitored with ultrasound velocity and the results are compiled in Figure 5. Results obtained for specimens consolidated with two different resins (“A”-methylphenylsilicone and “B”- epoxy) are also plotted for comparative purposes.

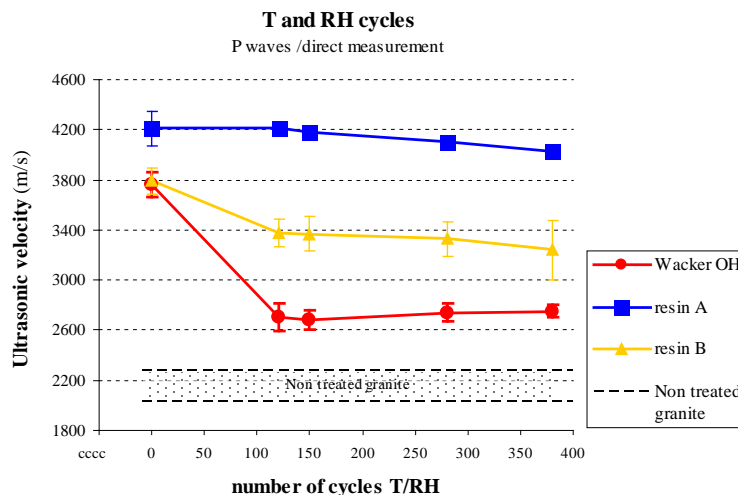


Figure 5 – Evolution of ultrasound velocity of specimens treated with Wacker OH during moistening/drying cycles in a climatic chamber (test A)

The original values of the ultrasound velocity on non-treated specimens are also plotted for reference. The product retained (see table 1) promotes an increase of ultrasound velocities as may be seen in cycle 0, and therefore it can be concluded that the treatment was effective, and that the consolidation action is not far from the action induced by the other tested resins. However, the initial efficiency of Wacker OH drops significantly to reach a much lower though a relatively constant value with increasing number of cycles. The mechanical resistance also decreased significantly, as shown by Vicente (1996b) or Delgado Rodrigues (1996b), a result that the values of this non-destructive test now confirm.

Test B

The results of the long-term immersion test (Figure 6) show a tendency similar to that of test A. The initial efficiency of Wacker OH drops significantly to reach a relatively constant level at a much lower value. The decrease in the bending strength of specimens consolidated with Wacker OH after immersion is in accordance with these results, previously published Vicente (1996b) and Delgado Rodrigues (1996b).

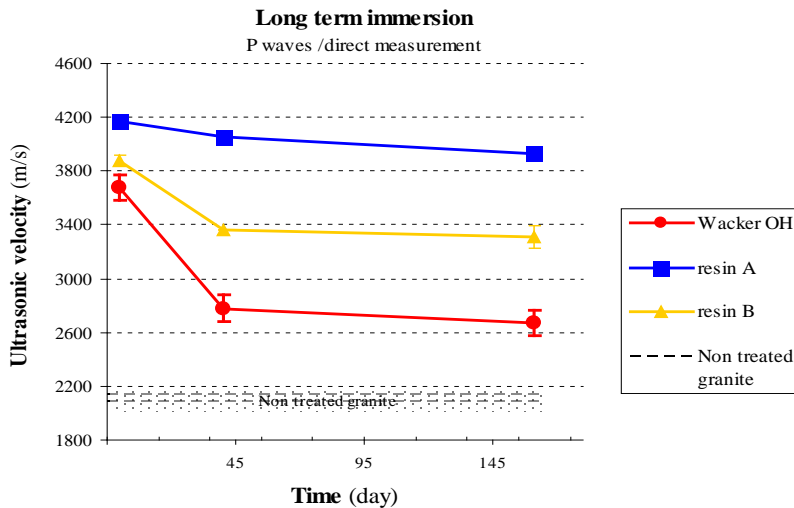


Figure 6 – Evolution in the ultrasound velocities of specimens treated with Wacker OH during long-term immersion (test B)

It must be said that resin A presents a strong water repellency behaviour due to its composition and this characteristic could have influenced the results. Besides, it also promotes unacceptable color changes to the original color of the granite, which are not possible to reverse later on any circumstances.

Test C

The water absorption/drying test is a mild test when compared with the immersion test. The percolation of water inside the material, followed by a slow drying process, is supposed to be a non-harmful action for consolidation treatments.

The results reported here (Figure 7) correspond to the behaviour of a slightly weathered granite. Some ashlar present in our monuments can have similar characteristics but usually they don't require consolidation.

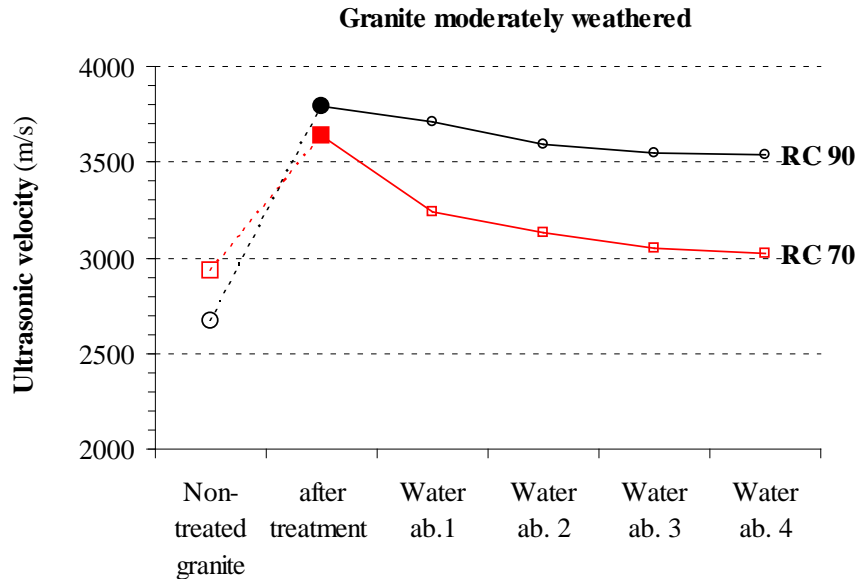


Figure 7 – Evolution of ultrasound velocity of granite specimens treated with RC70 and RC90, during water absorption/drying ageing phases (Water ab.1 to Water ab.4) after consolidation (test C)

As can be interpreted from the results (Figure 7), the two ethyl silicates have different consolidation effects: RC90 increases the cohesion of granite more than RC70 is able to. Percolation of water followed by drying decreased the original consolidation but the evolution seems to depend on the type of consolidation treatment. In fact, RC90 consolidating action resisted better than RC70.

Conclusion

Alkoxysilanes are currently used for the consolidation of stone. Their use on granites is particularly relevant and it can be said that we can hardly find a substitute for them.

In spite of the extreme variation in the formulations of products available in the market, in general all of them show a very good mobility on granite materials. This property is considered as absolutely decisive for the success of the consolidation of low porosity substrates. The chemical compatibility with silicate rocks is also a strong argument for their use on the consolidation of these rocks, and the information available indicates the possibility of chemical bonding between the major granite components and the gels formed, at least when the material to be consolidated is salt free.

In this paper results are presented that allow to conclude that the gels formed after polymerization of ethyl silicates increase the cohesion of granitic materials as was clearly demonstrated by the increment of the ultrasound velocities after consolidation. However, when submitted to conditions that involve the action of water, the original consolidation is rapidly changed (in the beginning of the process), even if some consolidating effect is kept after the test.

The results of distinct tests indicate that ethyl silicates are sensitive to water; be it a softer action such as absorption and drying or a strongest effect like the one caused by total immersion in water.

The explanation for this behaviour is not clear but the answer is certainly related to the characteristics of the gels formed. Several factors are recognized as determinant on the final properties of the gel but up to now their control and evaluation inside the rock was not systematically done.

These results raise other questions, some of them directly related to the use of ethyl silicates in stone conservation practice: Is the lack of durability only a concern for granitic substrates? Can the use of water repellent treatments solve or mitigate the effect of water on consolidated materials? Can we expect that new formulations might have an improved durability when exposed to the presence of water? All of these questions are very relevant for the use of alkoxysilanes on the consolidation of granite materials and constitute important topics for further research in this domain.

References

- Bosch, E. "Use of silicones in conservation of monuments". pp. 21-26 in *Proceedings of the 1st International symposium on the deterioration of building stones, La Rochelle, 11-16 September 1972*. Le centre de Recherches et d'études océanographiques, La Rochelle 1973.
- Costa, D. "*Métodos de avaliação laboratorial de tratamentos de Conservação aplicados em rochas graníticas*". Lisboa: Laboratório Nacional de Engenharia Civil, 1998.(in Portuguese)
- Costa, D. "*Avaliação de tratamentos para a conservação de superfícies graníticas arenizadas*". Lisboa: Laboratório Nacional de Engenharia Civil, 2007. (in Portuguese)
- Delgado Rodrigues, J. and D. Costa, (editors), *Conservation of granitic rocks*. Lisbon; Laboratório Nacional de Engenharia Civil, 1996.
- Delgado Rodrigues, J., D. Costa, M. Sá da Costa, I. Eusébio. "Behaviour of consolidated granites under ageing tests", in *Conservation of granitic rocks*. Lisbon; Laboratório Nacional de Engenharia Civil, 1996.
- Delgado Rodrigues, J. and D. Costa. "Assessment of the efficacy of consolidants in granites", in *Conservation of granitic rocks*. Lisbon; Laboratório Nacional de Engenharia Civil, 1996.
- Mamillan, M. "Connaissances actuelles pour mesurer le degré d'altération des pierres et l'efficacité des méthodes de traitements". pp. 47-56 in *Proceedings of the 1st International symposium on the deterioration of building stones, La Rochelle, 11-16 September 1972*. Le centre de Recherches et d'études océanographiques, La Rochelle 1973.
- RILEM - Commission 25 PEM Protection et érosion des Monuments (1980) - "Essais recommandés pour mesurer l'altération des pierres et évaluer l'efficacité des méthodes de traitement". *Matériaux et Constructions, Bull. RILEM*, 13 (75), pp. 216-220
- Schaffer, R. J. *The weathering of natural building stones*. Department of Scientific and industrial research. Building Research. Special report N°18. London, 1932 .
- Vicente, M.A., J. Delgado Rodrigues, J. Azevedo (editors). "Assessment of the efficacy of consolidants in granites" pp.343-354 in *Degradation and conservation of granitic rocks on monuments*. Proceedings of the EC Workshop held in Santiago de Compostela (Spain), November 28-30 1994. European Commission, Directorate-General XII, Science, Research and Development, Brussels 1996.
- Vicente, M.A., J. Delgado Rodrigues, J. Azevedo (editors). "Behaviour of consolidated granites under ageing tests" pp.355-360 in *Degradation and conservation of granitic rocks on monuments*. Proceedings of the EC Workshop held in Santiago de Compostela (Spain), November 28-30 1994. European Commission, Directorate-General XII, Science, Research and Development, Brussels 1996.
- Wendler, E. "New materials and approaches for the conservation of stone" pp. 181-196 in *Saving our architectural heritage*. Dahlem Workshop Report, Berlin, March 3-8 1996. England: John Wiley & Sons, 1997.
- Wheeler, G. *Alkoxysilanes and consolidation of stone*. Research in conservation. The Getty Conservation Institute, 2005.
- Wheeler, G. "Alkoxysilanes and consolidation of stone: Where we are now". pp.41-52 in *Proceedings of the International Symposium "Stone consolidation in Cultural Heritage. Research and Practice", Lisbon 6-7 May 2008*. Laboratório Nacional de Engenharia Civil. José Delgado Rodrigues & João-Manuel Mimoso (Editors). Lisbon, 2008.
- Yang, M., George W. Scherer and G.Wheeler. "Compatible consolidants" pp. 201-208 in *Compatible materials for the protection of European cultural Heritage*. PACT 56. Technical Chamber of Greece, 1998.

Materials and Suppliers

"Wacker OH" from WACKER (<http://www.wacker.com>):
Supplied by Wacker Química Portugal.

"Rhodorsil RC70" and "Rhodorsil RC90" from Rhodia Silicones; the company is now
<http://www.bluestarsilicones.com>
Supplied by CALDIC ESPAÑA, S.A.

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Dória Maria Rodrigues da Costa graduated in Geology from the University of Lisbon (Portugal) in 1983. She obtained the "Suficiencia Investigadora" from the University of Oviedo (Spain) in 2004, and is currently finishing a PhD thesis on the degradation of granite and its conservation. She entered the National Laboratory of Civil Engineering as a Trainee in 1991, eventually becoming a Research Trainee (1994), a Research Assistant (1998), and a Research Officer (since 2007). Her main research interests are conservation of stone (particularly of granite), durability of stone, and consequences of salts in stones and conservation treatments. She has participated in EU-funded projects such as "Degradation and conservation of granitic rocks with application to megalithic monuments"; "Device for hardness measurements of exposed monumental rocks - HARDROCK"; "ON SITE monitoring of biological colonization of stone and plaster surfaces using field portable fluorescence based techniques"; and "Effects of weathering on stone materials: assessment of their mechanical durability."

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José Delgado Rodrigues obtained a degree in Geology from the University of Coimbra (Portugal) and got the degree of "Especialista" from the National Laboratory of Civil Engineering in Lisbon (Portugal), where he is currently a Principal Research Officer. He has participated in several European projects on the conservation of granitic rocks, laser cleaning, and development of testing tools. He has also supervised several MSc and PhD theses and served as a lecturer in several European universities as well as International Centre for the Study of the Preservation and Restoration of Cultural Property (ICCROM) courses in conservation.

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